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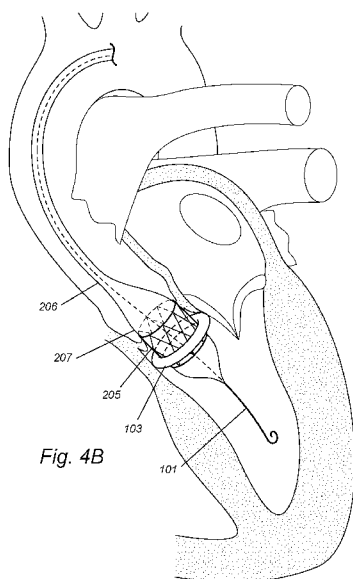
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(54) Title: DEVICES, SYSTEMS, AND METHODS TO OPTIMIZE ANNULAR ORIENTATION OF TRANSCATHETER VALVES



(57) Abstract: In various embodiments, provided herein are methods, devices and systems to optimize annular orientation of transcatheter valves and thereby facilitate transcatheter aortic valve replacement in the setting of challenging cardiovascular anatomy. These methods, devices and systems are used to treat patients with valvular diseases. To solve these problems, described herein is a Device to Optimize aNnUlar orientation of Transcatheter valves (DONUT). DONUT can correct large differences between a native valve's anatomical dimensions and the external dimensions of a transcatheter valve stent frame.

## **DEVICES, SYSTEMS, AND METHODS TO OPTIMIZE ANNULAR ORIENTATION OF TRANSCATHETER VALVES**

### **FIELD OF INVENTION**

**[0001]** This invention relates to devices, systems, and methods to optimize annular orientation of transcatheter valves, which may be used to treat valvular heart diseases.

### **BACKGROUND OF THE INVENTION**

**[0002]** All publications cited herein are incorporated by reference in their entirety to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference. The following description includes information that may be useful in understanding the present invention. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed invention, or that any publication specifically or implicitly referenced is prior art.

**[0003]** Valvular heart disease is characterized by damage to or a defect in one of the four heart valves: the mitral, aortic, tricuspid or pulmonary. The mitral and tricuspid valves control the flow of blood between the atria and the ventricles (the upper and lower chambers of the heart). The pulmonary valve controls the blood flow from the heart to the lungs, and the aortic valve governs blood flow between the heart and the aorta, and thereby to the blood vessels in the rest of the body. The mitral and aortic valves are most frequently affected by valvular heart disease.

**[0004]** Normally functioning valves ensure that blood flows with proper force in the proper direction at the proper time. In a valvular heart disease, a heart valve becomes too narrow and hardened (stenotic) to open fully, or is unable to close completely (incompetent). A stenotic valve forces blood to back up in the adjacent heart chamber, while an incompetent valve allows blood to leak back into the chamber it previously exited. To compensate for poor pumping action, the heart muscle enlarges and thickens, thereby losing elasticity and efficiency. In addition, in some cases, blood pooling in the chambers of the heart has a greater tendency to clot, increasing the risk of stroke or pulmonary embolism. The severity of valvular heart disease varies. In mild cases there may be no symptoms, while in advanced cases, valvular heart disease may lead to congestive heart failure and other complications. Treatment depends upon the extent of the disease.

[0005] Transcatheter valve therapies are one treatment option for patients. For example, transcatheter aortic valve replacement (TAVR - also known as TAVI or transcatheter aortic valve implantation) is a procedure for patients with severe symptomatic aortic stenosis (narrowing of the aortic valve opening) who are not candidates for traditional open chest surgery or are high-risk operable candidates. In these procedures, a replacement valve is inserted percutaneously using a catheter and implanted in the orifice of the native aortic valve. Replacement valves may be artificial (prosthetic valves) or made from animal tissue (bioprosthetic valves). Diseased mitral, tricuspid or pulmonary valves may also be treated with transcatheter valve replacement or implantation. The type of replacement valve selected depends on the patient's age, condition, and the specific valve affected.

[0006] Since transcatheter valves, unlike surgical valves, are not sewn into the heart, they require a landing zone to which their external profiles must conform and anchor to. Also, some degree of stenosis in the native valve is generally necessary to provide a consistently stable anchor point. However, the native valve's shape, size and stenosis vary considerably, and hence are not always favorable, suitable or safe for the deployment of transcatheter valves. If an implanted transcatheter valve does not conform to the native valve's anatomy or is not stably anchored, paravalvular leakage as well as device embolization or malposition may occur. To fill the gaps between the transcatheter valve and the native valve's anatomical structures, an external cuff (either fabric or hydrogel) may be added, but this cannot correct large differences in dimension.

## **SUMMARY OF THE INVENTION**

[0007] To solve these problems, described herein is a Device to Optimize aNnUlar orientation of Transcathether valves (DONUT). DONUT can correct large differences between a native valve's anatomical dimensions and the external dimensions of a transcatheter valve stent frame. DONUT may act as a mould for the anatomy of a native valve externally, and its central hole may match a transcatheter replacement valve, for example, a standardized valve or those commercially available ones including but not limited to the MEDTRONIC COREVALVE device and the EDWARDS SAPIEN device. The outside perimeter of the DONUT conforms to the anatomy of a native valve, cardiovascular structure or chamber, and its center hole fits a transcatheter valve. Also described herein is a method of using DONUT for transcatheter heart valve implantation. DONUT is first deployed to a diseased heart valve (e.g., the aortic valve and mitral valve) and serves as a

consistent landing zone and stable anchor point. Next, a transcatheter valve is implanted into the center hole of DONUT, even when the native valve's anatomy and stenosis are not favorable, suitable or safe for the direct deployment of a transcatheter valve.

**[0008]** The following embodiments and aspects thereof are described and illustrated in conjunction with devices, systems, and methods, which are meant to be exemplary and illustrative, not limiting in scope.

**[0009]** Provided herein are various embodiments of a device for a transcatheter valve replacement or implantation. The device may consist of, may consist essentially of, or may comprise a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive a replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber, herein also described as the "landing zone".

**[0010]** In various embodiments, provided herein is a device for a transcatheter valve replacement or implantation. In some embodiments, the device may consist of, may consist essentially of, or may comprise a replacement heart valve and a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive the replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve, cardiovascular structure or chamber.

**[0011]** In some embodiments, the device may consist of, may consist essentially of, or may comprise a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an

outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive a replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber; and a first delivery catheter, wherein the first delivery catheter is configured to deploy the ring-shaped article into the native heart valve peri-annular region.

**[0012]** In some embodiments, the device may consist of, may consist essentially of, or may comprise a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive a replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber; and a second delivery catheter, wherein the second delivery catheter is configured to deploy the replacement heart valve into the center hole of the ring-shaped article.

**[0013]** In various embodiments, the device described herein further comprises a guide wire, wherein a delivery catheter can be inserted over the guide wire. In various embodiments, the native heart valve may be a mitral, aortic, tricuspid or pulmonary valve.

**[0014]** Provided are various embodiments of a method for transcatheter valve replacement or implantation. In accordance with the present invention, the method may be used to treat a subject with valvular diseases. In some embodiments, the method may consist of, may consist essentially of, or may comprise the following steps: providing a device as described herein, deploying the device to a native heart valve peri-annular region; providing a replacement heart valve; and deploying the replacement heart valve into the center hole of the device. In various embodiments, the device and the replacement valve are deployed individually. In certain embodiments, the device is deployed before the replacement valve is deployed.

**BRIEF DESCRIPTION OF FIGURES**

[0015] Exemplary embodiments are illustrated in the referenced figures. It is intended that the embodiments and figures disclosed herein are to be considered illustrative rather than restrictive.

[0016] Figs. 1A-B depict, in accordance with various embodiments of the present invention, a self-expandable DONUT device and a transfemoral procedure of deploying the DONUT device to the aortic valve. **101** refers to a guide wire; **102** refers to a first delivery catheter; **103** refers to a self-expandable DONUT device; and **104** refers to an enclosing sheath at the first delivery catheter's distal end.

[0017] Figs. 1C-D depict, in accordance with various embodiments of the present invention, a self-expandable DONUT device and a transseptal procedure of deploying the DONUT device to the mitral valve. **101** refers to a guide wire; **102** refers to a first delivery catheter; **103** refers to a self-expandable DONUT device; and **104** refers to an enclosing sheath at the first delivery catheter's distal end.

[0018] Figs. 2A-C depict, in accordance with various embodiments of the present invention, a balloon-expandable DONUT device and a transfemoral procedure of deploying the DONUT device to the aortic valve. **201** refers to a guide wire; **202** refers to a first delivery catheter; **203** refers to a balloon-expandable DONUT device; and **204** refers to an inflatable balloon at the first delivery catheter's distal end.

[0019] Figs. 2D-F depict, in accordance with various embodiments of the present invention, a balloon-expandable DONUT device and a transseptal procedure of deploying the DONUT device to the mitral valve. **201** refers to a guide wire; **202** refers to a first delivery catheter; **203** refers to a balloon-expandable DONUT device; and **204** refers to an inflatable balloon at the first delivery catheter's distal end.

[0020] Figs. 3A-B depict, in accordance with various embodiments of the present invention, a self-expandable replacement valve and a transfemoral procedure of deploying the replacement valve to the center hole of the DONUT device that is already deployed in the aortic valve. **101** refers to a guide wire; **103** refers to an already deployed DONUT device; **105** refers to a self-expandable replacement valve; **106** refers to a second delivery catheter; and **107** refers to an enclosing sheath at the second delivery catheter's distal end.

[0021] Figs. 4A-C depict, in accordance with various embodiments of the present invention, a balloon-expandable replacement valve and a transfemoral procedure of deploying the replacement valve to the center hole of the DONUT device that is already deployed in the aortic valve. **101** refers to a guide wire; **103** refers to an already deployed DONUT device; **205** refers to a balloon-expandable replacement valve; **206** refers to a second delivery catheter; and **207** refers to an inflatable balloon at the first delivery catheter's distal end.

[0022] Fig. 5 depicts, in accordance with various embodiments of the present invention, one non-limiting example of DONUT in its expanded status. Fig. 5A shows that one non-limiting example of DONUT has an inward outside surface area (gray) that faces toward the center of the ring-shaped article and forms a center hole, and an outward outside surface area (white) that faces away from the center of the ring-shaped article and forms a periphery. Fig. 5B shows that one non-limiting example of DONUT has a stent frame covered with an external layer. After the DONUT device is anchored to a native heart valve peri-annular region, a replacement heart valve is anchored in its center hole to replace (or rather, implant within) the native heart valve.

## **DETAILED DESCRIPTION OF THE INVENTION**

[0023] All references cited herein are incorporated by reference in their entirety as though fully set forth. Unless defined otherwise, technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Singleton et al., *Dictionary of Microbiology and Molecular Biology* 3rd ed., J. Wiley & Sons (New York, NY 2001); March, *Advanced Organic Chemistry Reactions, Mechanisms and Structure* 5th ed., J. Wiley & Sons (New York, NY 2001); and Sambrook and Russel, *Molecular Cloning: A Laboratory Manual* 3rd ed., Cold Spring Harbor Laboratory Press (Cold Spring Harbor, NY 2001), provide one skilled in the art with a general guide to many of the terms used in the present application.

[0024] One skilled in the art will recognize many methods and materials similar or equivalent to those described herein, which could be used in the practice of the present invention. Indeed, the present invention is in no way limited to the methods and materials described. For purposes of the present invention, the following terms are defined below.

### *Devices and Systems*

[0025] Provided herein are various embodiments of a device for a transcatheter valve

replacement or implantation. In some embodiments, the device may consist of, may consist essentially of, or may comprise a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive a replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber. In various embodiments, the native heart valve may be a mitral, aortic, tricuspid or pulmonary valve. In certain embodiments, the device further comprises the replacement heart valve.

**[0026]** In various embodiments, the device further comprises a first delivery catheter, wherein the first delivery catheter is configured to deploy the ring-shaped article into the native heart valve peri-annular region.

**[0027]** In accordance with the present invention, the first delivery catheter can be comprised of one or more components. In some embodiments, the first delivery catheter comprises an inflatable balloon near or at its distal end, wherein the compressed ring-shaped article is configured to be mounted on the inflatable balloon, and wherein the inflatable balloon is configured to be inflated so as to expand the compressed ring-shaped article. In other embodiments, the first delivery catheter comprises an enclosing sheath near or at its distal end, wherein the compressed ring-shaped article is configured to be enclosed in the enclosing sheath, and wherein the enclosing sheath is configured to be retracted so as to expand the compressed ring-shaped article. In various embodiments, the enclosing sheath is just the distal portion of the first delivery catheter. In various embodiments, the enclosing sheath is a separate component located near or at the distal end of the first delivery catheter.

**[0028]** In various embodiments, the device further comprise a second delivery catheter, wherein the second delivery catheter is configured to deploy the replacement heart valve into the center hole of the ring-shaped article.

**[0029]** In some embodiments, the first delivery catheter and the second delivery catheter are the same delivery catheter. In other embodiments, the first delivery catheter and the second delivery catheter are two different delivery catheters.



**[0030]** In various embodiments, provided herein is a device for a transcatheter valve replacement or implantation. In some embodiments, the device may consist of, may consist essentially of, or may comprise a replacement heart valve and a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive the replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber.

**[0031]** In some embodiments, the device may consist of, may consist essentially of, or may comprise a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive a replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber; and a first delivery catheter, wherein the first delivery catheter is configured to deploy the ring-shaped article into the native heart valve peri-annular region.

**[0032]** In some embodiments, the device may consist of, may consist essentially of, or may comprise a ring-shaped article, wherein the ring-shaped article comprises an outside surface, wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole, wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery, wherein the ring-shaped article has a compressed status and an expanded status, and wherein when the ring-shaped article is expanded, the center hole is configured to receive a replacement heart valve and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber; and a second delivery catheter, wherein the second delivery catheter is configured to deploy the replacement heart valve into the center hole of the ring-shaped article.

**[0033]** In various embodiments, the device further comprises a guide wire. In one embodiment, the first delivery catheter is configured to be inserted over the guide wire. In another embodiment, the second delivery catheter is configured to be inserted over the guide wire.

**[0034]** In various embodiments, the periphery of the ring-shaped article is configured to anchor to the native heart valve peri-annular region. In one embodiment, the periphery is configured to anchor to the ventricular side of the native heart valve. In another embodiment, the periphery is configured to anchor to the atrial side of the native heart valve. Still in another embodiment, the periphery is configured to anchor to the aorta or arterial side of the native heart valve. Still in another embodiment, the periphery is configured to anchor to another cardiovascular structure or chamber, including but not restricted to the right atrial surface, the superior vena cava, the inferior vena cava or the pulmonary artery.

**[0035]** In various embodiments, the periphery is configured to anchor onto the annulus of the native valve or valve annulus. In various embodiments, the periphery is configured to anchor onto the ventricular wall near the valve annulus. In various embodiments, the periphery is configured to anchor onto the atrial wall near the valve annulus. In various embodiments, the periphery is configured to anchor onto the aortic wall near the valve annulus. In various embodiments, the periphery is configured to anchor the arterial wall near the valve annulus. In some embodiments, the periphery is configured to anchor not onto the valve annulus but onto the ventricular wall, the atrial wall, the aortic wall, or the arterial wall near the valve annulus. In other embodiments, the periphery is configured to anchor onto the valve annulus and onto the ventricular wall, the atrial wall, the aortic wall, or the arterial wall near the valve annulus. In some embodiments, the anchored periphery pushes the native leaflets aside. In other embodiments, the anchored periphery does not push the native leaflets aside.

**[0036]** In various embodiments, the ring-shaped article is about 5-55 mm in height. In various embodiments, the center hole of the ring-shaped article is about 10-55 mm in diameter. In various embodiments, the periphery of the ring-shaped article is about 15-80 mm in diameter. In some embodiments, the “diameter” used herein refers to the periphery’s diameter (i.e., peripheral diameter) when the device is expanded. In various embodiments, the periphery of the ring-shaped article has an adjustable diameter. A user may measure the native valve’s dimensions, adjust the periphery’s diameter to fit the size and shape of the native valve, compress and load the device to a delivery catheter, deliver and deploy the

device to the native valve, to which the periphery of the expanded device conforms and anchors. In one embodiment, the ring-shaped article's height is less than the replacement valve's height. In another embodiment, the ring-shaped article's height is about 5-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, 70-80%, 80-90%, or 90-95% of the replacement valve's height. In various embodiments, the ring-shaped article does not have a diaphragm.

**[0037]** In various embodiments, the ring-shaped article is shaped as a circular, elliptical, oval, or D ring, or other suitable shapes that conform to a native heart valve peri-annular region. In various embodiments, the periphery is shaped as a circular, elliptical, oval, or D ring, or other suitable shapes that conform to a native heart valve peri-annular region. In various embodiments, the center hole is shaped as a circular, elliptical, oval, or D ring, or other suitable shapes that accommodate a replacement heart valve. In various embodiments, the center hole's shape matches the replacement valve's shape.

**[0038]** In various embodiments, the ring-shaped article is self-expandable or balloon expandable. In various embodiments, the ring-shaped article comprises a stent frame. In some embodiments, the stent frame of the ring-shaped article is made of iron, platinum, titanium, nickel, chromium, cobalt, magnesium, stainless steel, nitinol (nickel-titanium), nickel-chromium, cobalt-chromium, or platinum-iridium, or a combination thereof.

**[0039]** In various embodiments, the ring-shaped article comprises an external layer over the stent frame. In some embodiments, the external layer is made of an animal tissue or a synthetic material, or a combination thereof. Examples of suitable animal tissues include but are not limited to bovine-derived, porcine-derived, equine-derived, human-derived cardiovascular or stem-cell derived tissues. Examples of suitable synthetic materials include but are not limited to polyester fabric, hydrogel, plastic resin, expansile polymer or inflatable hollow plastic material.

**[0040]** In various embodiments, the ring-shaped article comprises entirely a hollow plastic material that may be inflated with air, fluid or a plastic resin.

**[0041]** In various embodiments, the replacement heart valve is configured to anchor to the center hole of the ring-shaped article. In various embodiments, the ring-shaped and the replacement heart valve are separate items and are individually delivered and/or deployed. In certain embodiments, the ring-shaped article is deployed before the replacement heart valve

is deployed.

**[0042]** In some embodiments, the ring-shaped article and the replacement heart valve are not connected to each other before, during or after their deployment. In other embodiments, the ring-shaped article and the replacement heart valve are not connected before deployment and are connected after deployment. In various embodiments, the ring-shaped article and the replacement heart valve are connected via a connector including but not limited to a hinge, click-and-lock system, tongue-and-groove system, interlocking structure, clasp, hook, ring, bolts, nut, screw, nail, fastener, magnet, mortise and/or tenon. In some embodiments, the connector comprises two or more components, for example, a click-and-lock system or a tongue-and-groove system. In other embodiments, the connector comprises only one component, for example, a bridge, string, wire, beam or joist.

**[0043]** In various embodiments, the replacement heart valve is about 10-55 mm in height. In various embodiments, the replacement heart valve is about 10-55 mm in diameter.

**[0044]** In various embodiments, the cross section of the replacement valve is a circle, ellipse, oval, or D-shape, or other suitable shapes that accommodate a native heart valve. In various embodiments, the cross section of the replacement valve is a circle, ellipse, oval, or D-shape, or other suitable shapes that accommodate the center hole of the ring-shaped article. In various embodiments, the replacement valve's shape matches with the center hole's shape.

**[0045]** In various embodiments, the replacement heart valve is a self-expandable valve, a balloon expandable valve, or any other suitable replacement valve. A non-limiting example of a self-expandable replacement valve is the MEDTRONIC COREVALVE, which is constructed with a nitinol self-expanding valve stent frame and porcine pericardial leaflets. A non-limiting example of a balloon-expandable replacement valve is the EDWARDS SAPIEN XT VALVE, which is constructed with a cobalt-chromium balloon-expandable valve stent frame and bovine pericardial leaflets.

**[0046]** In various embodiments, the replacement valve comprises a stent frame. In some embodiments, the stent frame of the replacement valve is made of iron, platinum, titanium, nickel, chromium, cobalt, magnesium, stainless steel, nitinol (nickel-titanium), nickel-chromium, cobalt-chromium, or platinum-iridium, or a combination thereof.

**[0047]** In some embodiments, the replacement heart valve is a prosthetic valve, a bioprosthetic valve, or any other suitable replacement valve. In accordance with the present

invention, a prosthetic valve is made of purely artificial or non-biological materials, and a bioprosthetic valve is made of animal tissues alone or in combination with artificial or non-biological materials. In various embodiments, the replacement valve comprises one, two, three, or more leaflets. In various embodiments, the leaflets may be biological or artificial.

**[0048]** Suitable examples of guide wires, sheaths, and catheters that may be utilized with the presently disclosed devices, systems and methods described herein will be apparent to a person of skill in the art. Examples of suitable guidewires, sheaths and catheters are disclosed in for example, Ye et al. (Transapical aortic valve implantation in humans. Ye J, Cheung A, Lichtenstein SV, Carere RG, Thompson CR, Pasupati S, Webb JG. J Thorac Cardiovasc Surg. 2006 May; 131(5):1194-6) and Lichtenstein et al. (Transapical transcatheter aortic valve implantation in humans: initial clinical experience. Lichtenstein SV, Cheung A, Ye J, Thompson CR, Carere RG, Pasupati S, Webb JG. Circulation. 2006 Aug 8; 114 (6):591-6. Epub 2006 Jul 31), the contents of each of which are herein incorporated by reference.

**[0049]** Materials which may be used to construct the device are well known in the art, for example as described in U.S. Publication No. US2011/0319989, which is incorporated by reference herein in its entirety.

### ***Methods***

**[0050]** Provided are various embodiments of a method for transcatheter valve replacement or implantation. In accordance with the present invention, the method may be used to treat a subject with valvular diseases. In some embodiments, the method may consist of, may consist essentially, or may comprise the following steps: providing a device as described herein, deploying the device to a native heart valve peri-annular region; providing a replacement heart valve; and deploying the replacement heart valve into the center hole of the device. In various embodiments, the device and the replacement valve are deployed individually. In certain embodiments, the device is deployed before the replacement valve is deployed.

**[0051]** In various embodiments, the device may be deployed antegradely (i.e., along the blood flow direction) or retrogradely (i.e., against the blood flow direction). In some embodiments, the device is deployed transfemorally, transaortically, transseptally, transapically, or by alternative arterial or venous approach. In some embodiments, the replacement valve is deployed transfemorally, transaortically, transseptally, transapically, or

by alternative arterial or venous approach.

**[0052]** In various embodiments, the device and the replacement valve are not connected before, during, after their deployment. In various embodiments, the device and the replacement valve are connected not before but after their deployment.

**[0053]** In various embodiments, deploying the device comprises delivering the compressed device to the native heart valve peri-annular region, expanding the compressed device in the native heart valve peri-annular region and anchoring the expanded device to the native heart valve peri-annular region. In some embodiments, the compressed device is balloon-expandable, and is deployed using a delivery catheter having an inflatable balloon at or near the distal end of the delivery catheter. In other embodiments, the compressed device is self-expandable, and is deployed using a delivery catheter having an enclosing sheath at or near the distal end of the delivery catheter.

**[0054]** In various embodiments, anchoring comprises anchoring the expanded device onto the valve annulus. In various embodiments, anchoring comprises anchoring the expanded device onto the ventricular wall near the valve annulus. In various embodiments, anchoring comprises anchoring the expanded device onto the atrial wall near the valve annulus. In various embodiments, anchoring comprises anchoring the expanded device onto the aortic wall near the valve annulus. In various embodiments, anchoring comprises anchoring the expanded device onto the arterial wall near the valve annulus.

**[0055]** One of the core principles of the invention is that the device should not disrupt the native valve itself so as to prevent hemodynamic compromise. In some examples, the device may be deployed in a cardiovascular structure or chamber distinct from the native valves to act as a platform for deployment of a transcatheter valve. In some examples, this distinct cardiovascular structure or chamber may include but is not restricted to the superior or inferior vena cava, the pulmonary artery or the ascending or descending aorta.

**[0056]** In various embodiments, the subject is a human. In various embodiments, the subject is a mammal. In various embodiments, the devices, systems and methods described herein are configured for humans. One of skill in the art would readily appreciate that the devices, systems and methods described herein could be customized for use in almost any mammal in which a heart valve may be replaced. "Mammal" as used herein refers to any member of the class Mammalia, including but not limited to, humans, domestic animals, farm animals, zoo

animals, sport animals, pet animals such as dogs, cats, guinea pigs, rabbits, rats, mice, horses, cattle, cows; primates such as apes, monkeys, orangutans, and chimpanzees; canids such as dogs and wolves; felids such as cats, lions, and tigers; equids such as horses, donkeys, and zebras; food animals such as cows, pigs, and sheep; ungulates such as deer and giraffes; rodents such as mice, rats, hamsters and guinea pigs; and so on. In certain embodiments, the mammal is a human subject. The term does not denote a particular age or sex. Thus, adult, newborn, fetuses, male or female mammalian heart surgery is within the scope of this disclosure.

[0057] Also in accordance with the present invention, as regular TAVR and TMVR are known surgical procedures, one of ordinary skill in the art would readily recognize that the method could involve other additional steps, which are not described in details here. These additional steps include, but are not limited to, anesthesia, sterilization, heparinization, accessing the patient's heart via various routes such as transfemoral, transaortic, transapical, transseptal, transcaval, transaxillary, and transsubclavian approaches, ventricular pacing, stitching of the access site or percutaneous femoral closure. For example, more information on these procedures are described in Masson et al. (Percutaneous treatment of mitral regurgitation; *Circ Cardiovasc Interv.* 2009 Apr.;2(2):140-6.) and Chiam et al. (Percutaneous transcatheter mitral valve repair: a classification of the technology; *JACC Cardiovasc Interv.* 2011 Jan.4(1):1-13.), each of which is incorporated herein by reference in its entirety.

## **EXAMPLES**

[0058] The following examples are provided to better illustrate the claimed invention and are not to be interpreted as limiting the scope of the invention. To the extent that specific materials are mentioned, it is merely for purposes of illustration and is not intended to limit the invention. One skilled in the art may develop equivalent means or reactants without the exercise of inventive capacity and without departing from the scope of the invention.

### ***Example 1 Self-Expandable DONUT***

#### ***For Aortic Valve***

[0059] Figs. 1A-1B illustrate an example of an implantation procedure for a DONUT device as disclosed herein. After induction of anesthesia, and sterile preparation, an incision is performed at the femoral artery. Alternatively, percutaneous femoral access may be performed with or without pre-closure. A guide wire **101** is inserted via the femoral artery

and the ascending aorta through the aortic valve into the left ventricle (Fig. 1A). A self-expandable DONUT device **103** is compressed and enclosed in the enclosing sheath **104** at the distal end of a first delivery catheter **102**. The loaded first delivery catheter **102** is advanced over the guide wire **101** and inserted through the aortic valve into the left ventricle, and places the compressed DONUT device **103** on the ventricular side of the aortic valve and near the valve annulus (Fig. 1A). The first delivery catheter **102** is retracted and the compressed DONUT device **103** is hence released out of the enclosing sheath **104** to expand (Fig. 1B). The expanded DONUT device's periphery conforms to the aortic valve's peri-annular anatomy and anchors to the ventricular wall near the valve annulus (Fig. 1B).

#### *For Mitral Valve*

**[0060]** Figs. 1C-1D illustrate an example of an implantation procedure for a DONUT device as disclosed herein. After induction of anesthesia, and sterile preparation, an incision is performed at the femoral vein. Alternatively, percutaneous femoral access may be performed with or without pre-closure. A guide wire **101** is inserted via the femoral vein and the right atrium, through a transseptal puncture on the inter-atrium septum, into the left atrium, thorough the mitral valve and into the left ventricle (Fig. 1C). A self-expandable DONUT device **103** is compressed and enclosed in the enclosing sheath **104** at the distal end of a first delivery catheter **102**. The loaded first delivery catheter **102** is advanced over the guide wire **101** and inserted through the mitral valve into the left ventricle, and places the compressed DONUT device **103** on the atrial side of the mitral valve and near the valve annulus (Fig. 1C). The first delivery catheter **102** is retracted and the compressed DONUT device **103** is hence released out of the enclosing sheath **104** to expand (Fig. 1D). The expanded DONUT device's periphery conforms to the mitral valve's peri-annular anatomy and anchors to the atrial wall near the valve annulus (Fig. 1D).

#### ***Example 2 Balloon-Expandable DONUT***

##### *For Aortic Valve*

**[0061]** Figs. 2A-2C illustrate an example of an implantation procedure for a DONUT device as disclosed herein. After induction of anesthesia, and sterile preparation, an incision is performed at the femoral artery. Alternatively, percutaneous femoral access may be performed with or without pre-closure. A guide wire **201** is inserted via the femoral artery and the ascending aorta through the aortic valve into the left ventricle (Fig. 2A). A balloon-



expandable DONUT device **203** is compressed and mounted over the inflatable balloon **204** at the distal end of a first delivery catheter **202**. The loaded first delivery catheter **202** is advanced over the guide wire **201** and inserted through the aortic valve into the left ventricle, and places the compressed DONUT device **203** on the ventricular side of the aortic valve and near the valve annulus (Fig. 2A). The inflatable balloon **204** is inflated to expand the compressed DONUT device **203** (Fig. 2B). The expanded DONUT device's periphery conforms to the aortic valve's peri-annular anatomy and anchors to the ventricular wall near the valve annulus (Fig. 2B). The inflatable balloon **204** is deflated and the first delivery catheter **202** is retracted (Fig. 2C).

#### *For Mitral Valve*

**[0062]** Figs. 2D-1F illustrate an example of an implantation procedure for a DONUT device as disclosed herein. After induction of anesthesia, and sterile preparation, an incision is performed at the femoral vein. Alternatively, percutaneous femoral access may be performed with or without pre-closure. A guide wire **201** is inserted via the femoral vein and the right atrium, through a transseptal puncture on the inter-atrium septum, into the left atrium, thorough the mitral valve and into the left ventricle (Fig. 2D). A balloon-expandable DONUT device **203** is compressed and mounted over the inflatable balloon **204** at the distal end of a first delivery catheter **202**. The loaded first delivery catheter **202** is advanced over the guide wire **201** and inserted through the mitral valve into the left ventricle, and places the compressed DONUT device **203** on the atrial side of the mitral valve and near the valve annulus (Fig. 2D). The inflatable balloon **204** is inflated to expand the compressed DONUT device **203** (Fig. 2E). The expanded DONUT device's periphery conforms to the mitral valve's peri-annular anatomy and anchors to the atrial wall near the valve annulus (Fig. 2E). The inflatable balloon **204** is deflated and the first delivery catheter **202** is retracted (Fig. 2F).

#### *Example 3 Delivery of Self-Expandable Replacement Valve*

**[0063]** This is performed after the DONUT device is deployed to the aortic valve peri-annular region. A self-expandable replacement valve **105** is compressed and enclosed in the enclosing sheath **107** at the distal end of a second delivery catheter **106**. The loaded second delivery catheter **106** is advanced over the guide wire **101** and inserted through the aortic valve into the left ventricle, and places the compressed replacement valve **105** across the aortic valve and the center hole of the DONUT device (Fig. 3A). The second delivery catheter **106** is retracted and the compressed replacement valve **105** is hence released out of

the enclosing sheath **107** to expand (Fig. 3B). The expanded replacement valve anchors to the center hole of the DONUT device, thereby replacing the native aortic valve (Fig. 3B).

**[0064]** In various embodiments, the same or similar steps may be used for other heart valves, such as the mitral valve, pulmonary valve and tricuspid valve, in which cases the DONUT is first deployed to the respective heart valve peri-annular region. In various embodiments, the DONUT may be deployed in a cardiovascular structure or chamber distinct from the native valves to act as a platform for deployment of a transcatheter valve. This may include but is not restricted to the superior or inferior vena cava, the pulmonary artery or the ascending or descending aorta.

**[0065]** Additional standard steps that may be performed during the procedure include heparinization, and closure of the femoral artery or vein either by manual compression, suture-mediated pre-closure or surgical closure. The procedure may be performed by local anesthesia with conscious sedation or general anesthesia, in which case the patient is generally woken up immediately after the procedure. Heparinization may be reversed at the end of the procedure by administration of protamine. Heparin intolerant individuals may be anticoagulated during the procedure using direct thrombin inhibitors.

#### ***Example 4 Delivery of Balloon-Expandable Replacement Valve***

**[0066]** This is performed after the DONUT device is deployed to the aortic valve peri-annular region. A balloon-expandable replacement valve **205** is compressed and mounted over the inflatable balloon **207** at the distal end of a second delivery catheter **206**. The loaded second delivery catheter **206** is advanced over the guide wire **101** and inserted through the aortic valve into the left ventricle, and places the compressed replacement valve **205** across the aortic valve and the center hole of the DONUT device (Fig. 4A). The inflatable balloon **207** is inflated to expand the compressed DONUT device **205** (Fig. 4B). The expanded replacement valve **205** anchors to the center hole of the DONUT device, thereby replacing the native aortic valve (Fig. 4B). The inflatable balloon **207** is deflated and the second delivery catheter **206** is retracted (Fig. 4C).

**[0067]** In various embodiments, the same or similar steps may be used for other heart valves, such as the mitral valve, pulmonary valve and tricuspid valve, in which cases the DONUT is first deployed to the respective heart valve.

**[0068]** Additional standard steps that may be performed during the procedure include

heparinization, and closure of the femoral artery or femoral vein either by manual compression, suture-mediated pre-closure or surgical closure. The procedure may be performed by local anesthesia with conscious sedation or general anesthesia, in which case the patient is generally woken up immediately after the procedure. Heparinization may be reversed at the end of the procedure by administration of protamine. Heparin intolerant individuals may be anticoagulated during the procedure using direct thrombin inhibitors.

**[0069]** The various methods and techniques described above provide a number of ways to carry out the application. Of course, it is to be understood that not necessarily all objectives or advantages described can be achieved in accordance with any particular embodiment described herein. Thus, for example, those skilled in the art will recognize that the methods can be performed in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objectives or advantages as taught or suggested herein. A variety of alternatives are mentioned herein. It is to be understood that some preferred embodiments specifically include one, another, or several features, while others specifically exclude one, another, or several features, while still others mitigate a particular feature by inclusion of one, another, or several advantageous features.

**[0070]** Furthermore, the skilled artisan will recognize the applicability of various features from different embodiments. Similarly, the various elements, features and steps discussed above, as well as other known equivalents for each such element, feature or step, can be employed in various combinations by one of ordinary skill in this art to perform methods in accordance with the principles described herein. Among the various elements, features, and steps some will be specifically included and others specifically excluded in diverse embodiments.

**[0071]** Although the application has been disclosed in the context of certain embodiments and examples, it will be understood by those skilled in the art that the embodiments of the application extend beyond the specifically disclosed embodiments to other alternative embodiments and/or uses and modifications and equivalents thereof.

**[0072]** In some embodiments, the terms “a” and “an” and “the” and similar references used in the context of describing a particular embodiment of the application (especially in the context of certain of the following claims) can be construed to cover both the singular and the plural. The recitation of ranges of values herein is merely intended to serve as a shorthand method of referring individually to each separate value falling within the range. Unless

otherwise indicated herein, each individual value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (for example, “such as”) provided with respect to certain embodiments herein is intended merely to better illuminate the application and does not pose a limitation on the scope of the application otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the application.

**[0073]** Preferred embodiments of this application are described herein, including the best mode known to the inventors for carrying out the application. Variations on those preferred embodiments will become apparent to those of ordinary skill in the art upon reading the foregoing description. It is contemplated that skilled artisans can employ such variations as appropriate, and the application can be practiced otherwise than specifically described herein. Accordingly, many embodiments of this application include all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the application unless otherwise indicated herein or otherwise clearly contradicted by context.

**[0074]** All patents, patent applications, publications of patent applications, and other material, such as articles, books, specifications, publications, documents, things, and/or the like, referenced herein are hereby incorporated herein by this reference in their entirety for all purposes, excepting any prosecution file history associated with same, any of same that is inconsistent with or in conflict with the present document, or any of same that may have a limiting affect as to the broadest scope of the claims now or later associated with the present document. By way of example, should there be any inconsistency or conflict between the description, definition, and/or the use of a term associated with any of the incorporated material and that associated with the present document, the description, definition, and/or the use of the term in the present document shall prevail.

**[0075]** It is to be understood that the embodiments of the application disclosed herein are illustrative of the principles of the embodiments of the application. Other modifications that can be employed can be within the scope of the application. Thus, by way of example, but not of limitation, alternative configurations of the embodiments of the application can be

utilized in accordance with the teachings herein. Accordingly, embodiments of the present application are not limited to that precisely as shown and described.

**CLAIMS**

1. A device for transcatheter valve replacement, comprising:
  - a ring-shaped article,
  - wherein the ring-shaped article comprises an outside surface,
  - wherein the outside surface comprises an inward surface area that faces toward the center of the ring-shaped article and forms a center hole,
  - wherein the outside surface comprises an outward surface area that faces away from the center of the ring-shaped article and forms a periphery,
  - wherein the ring-shaped article has a compressed status and an expanded status
  - wherein when the ring-shaped article is expanded, the center hole is configured to receive a replacement heart valve, and the periphery is configured to conform to the anatomy of a native heart valve peri-annular region, cardiovascular structure or chamber
  - wherein the center hole is perfectly configured to facilitate conformity of deployment of a commercially available stented transcatheter valve;
  - wherein the periphery expands to an irregular conformation to conform to the native anatomy (native heart valve peri-annular region, cardiovascular structure or chamber)
  - wherein the device may be deployed in a cardiovascular structure or chamber distinct from the native valves to act as a platform for deployment of a transcatheter valve; this may include but is not restricted to the superior or inferior vena cava, the pulmonary artery or the ascending or descending aorta.
2. The device of claim 1, wherein the native heart valve is a mitral, aortic, tricuspid or pulmonary valve.
3. The device of claim 1, wherein the periphery is configured to anchor to the native heart valve peri-annular region.
4. The device of claim 1, wherein the periphery is configured to anchor to the ventricular, atrial, aortic, or arterial wall.
5. The device of claim 1, wherein the replacement heart valve is configured to anchor to the center hole of the ring-shaped article.

6. The device of claim 1, wherein the ring-shaped article and the replacement heart valve are not connected to each other.
7. The device of claim 1, wherein the replacement heart valve is about 10-55 mm in height.
8. The device of claim 1, wherein the ring-shaped article is about 5-55 mm in height.
9. The device of claim 1, wherein the replacement heart valve is about 10-55 mm in diameter.
10. The device of claim 1, wherein the center hole of the ring-shaped article is about 10-55 mm in diameter.
11. The device of claim 1, wherein the periphery of the ring-shaped article is about 15-80 mm in diameter.
12. The device of claim 1, wherein the center hole of the ring-shaped article is shaped as a circular, elliptical, oval, or D ring and the periphery of the ring-shaped article is shaped to conform to the region in which the device is deployed.
13. The device of claim 1, wherein the cross section of the replacement valve is a circle, ellipse, oval, or D-shape.
14. The device of claim 1, wherein the ring-shaped article is self-expandable or balloon expandable.
15. The device of claim 1, wherein the ring-shaped article comprises a frame made of iron, platinum, titanium, nickel, chromium, cobalt, magnesium, stainless steel, nitinol (nickel-titanium), nickel-chromium, cobalt-chromium, or platinum-iridium, or a combination thereof, or of a solid or hollow plastic material.
16. The device of claim 1, wherein the replacement heart valve is self-expandable or balloon expandable.
17. The device of claim 1, wherein the replacement valve comprises a stent frame made of iron, platinum, titanium, nickel, chromium, cobalt, magnesium, stainless steel, nitinol (nickel-titanium), nickel-chromium, cobalt-chromium, or platinum-iridium, or a combination thereof, or of a solid or hollow plastic material.

18. The device of claim 1, wherein the replacement heart valve is a prosthetic valve or a bioprosthetic valve.
19. The device of claim 1, wherein the replacement valve comprises one, two, three, or more leaflets.
20. The device of claim 1, further comprising the replacement heart valve.
21. The device of claim 1, further comprising a first delivery catheter, wherein the first delivery catheter is configured to deploy the ring-shaped article into the native heart valve peri-annular region or alternative cardiovascular location.
22. The device of claim 21, wherein the first delivery catheter comprises an inflatable balloon near or at its distal end, wherein the compressed ring-shaped article is configured to be mounted on the inflatable balloon, and wherein the inflatable balloon is configured to be inflated so as to expand the compressed ring-shaped article.
23. The device of claim 21, wherein the first delivery catheter comprises an enclosing sheath near or at its distal end, wherein the compressed ring-shaped article is configured to be enclosed in the enclosing sheath, and wherein the enclosing sheath is configured to be retracted so as to expand the compressed ring-shaped article.
24. The device of claim 21, further comprising a guide wire, wherein the first delivery catheter is configured to be inserted over the guide wire.
25. The device of claim 1, further comprising a second delivery catheter, wherein the second delivery catheter is configured to deploy the replacement heart valve into the center hole of the ring-shaped article.
26. The device of claim 25, further comprising a guide wire, wherein the second delivery catheter is configured to be inserted over the guide wire.
27. A method for transcatheter valve replacement, comprising:
  - providing the device of claim 1;
  - deploying the device into a native heart valve;
  - providing a replacement heart valve; and
  - deploying the replacement heart valve into the center hole of the device.
28. The method of claim 27, wherein the device is deployed transfemorally,



- transaortically, transseptally, transapically, or by alternative venous or arterial approach.
29. The method of claim 27, wherein the replacement valve is deployed transfemorally, transaortically, transseptally, transapically, or by alternative venous or arterial approach.
  30. The method of claim 27, wherein deploying the device comprises delivering the compressed device to the native heart valve peri-annular region, expanding the compressed device in the native heart valve peri-annular region and anchoring the expanded device to the native heart valve peri-annular region.
  31. The method of claim 30, wherein anchoring comprises anchoring the expanded device onto the valve annulus peri-annular region.
  32. The method of claim 30, wherein anchoring comprises anchoring the expanded device onto the ventricular wall near the valve annulus.
  33. The method of claim 30, wherein anchoring comprises anchoring the expanded device onto the atrial wall near the valve annulus.
  34. The method of claim 30, wherein anchoring comprises anchoring the expanded device onto the aorta wall near the valve annulus.
  35. The method of claim 30, wherein anchoring comprises anchoring the expanded device onto the arterial wall near the valve annulus.
  36. The method of claim 30, wherein anchoring comprises anchoring the expanded device not onto the valve annulus peri-annular region but onto the ventricular wall, the atrial wall, the aortic wall, or the arterial wall near the valve annulus.
  37. The method of claim 30, wherein anchoring comprises anchoring the expanded device not onto the valve annulus peri-annular region but onto the ventricular wall, the atrial wall, the aortic wall, or the arterial wall far from the valve annulus.
  38. The method of claim 30, wherein the anchored device pushes the native leaflets aside.
  39. The method of claim 30, wherein the anchored device does not push the native leaflets aside.

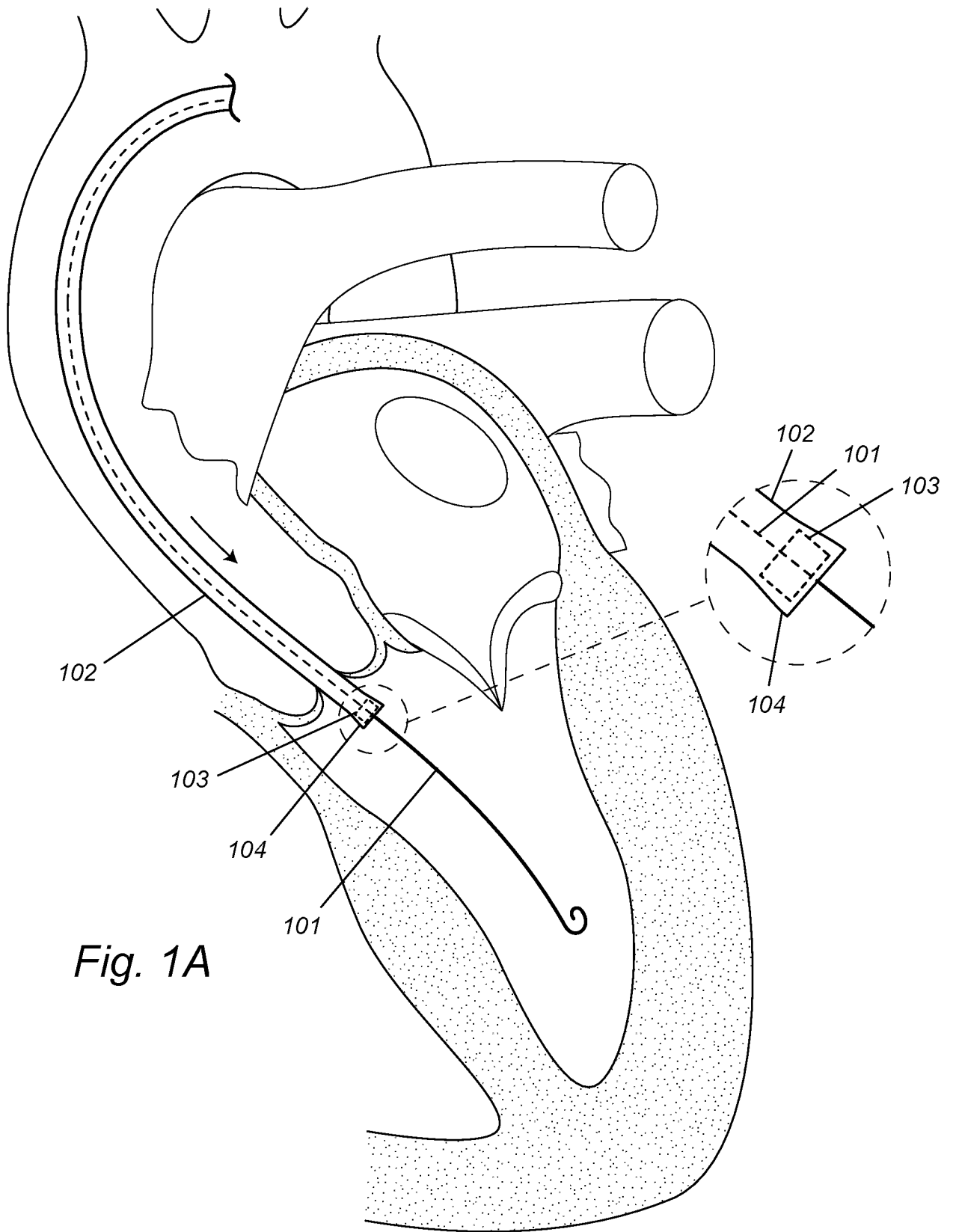
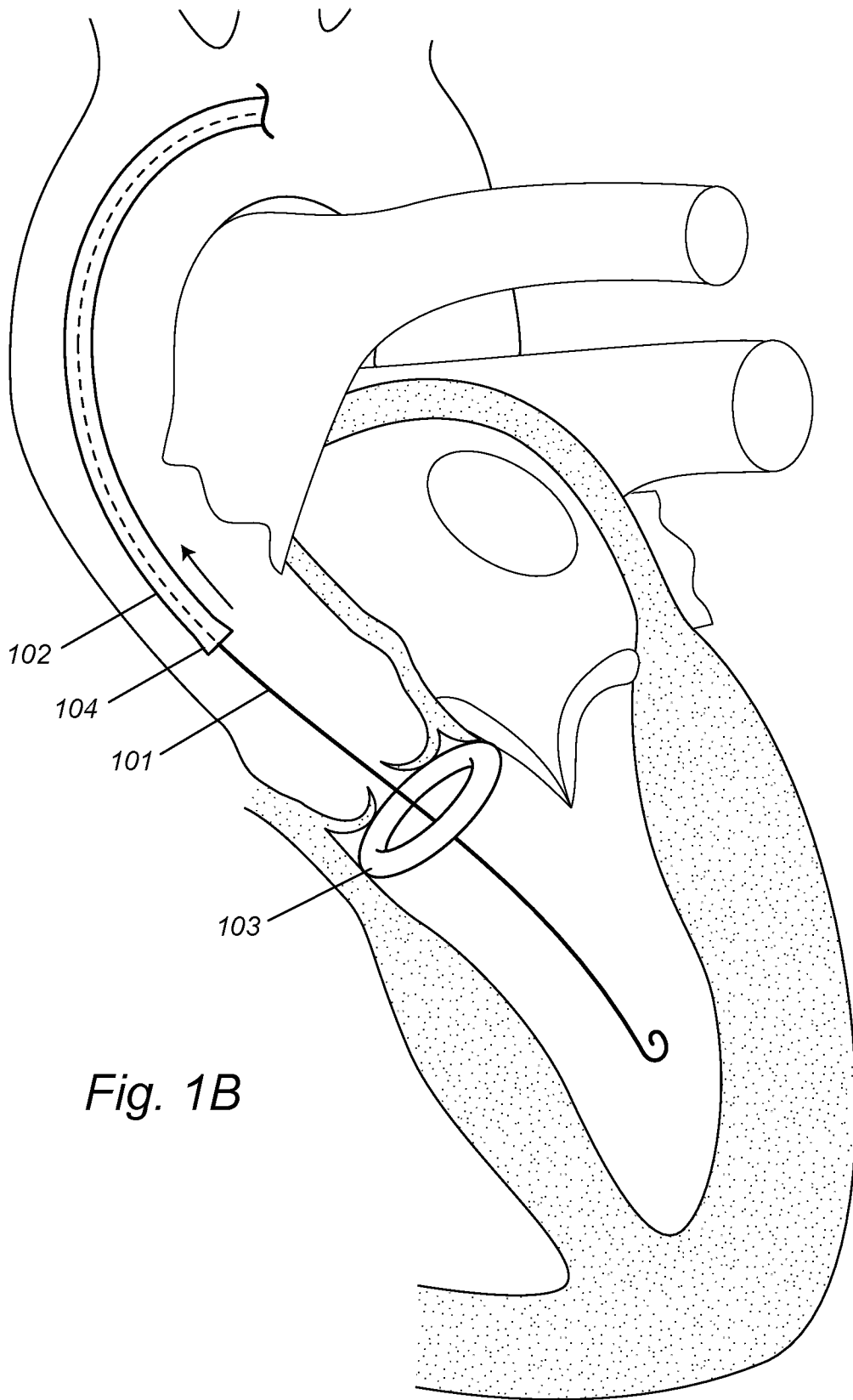


Fig. 1A



*Fig. 1B*

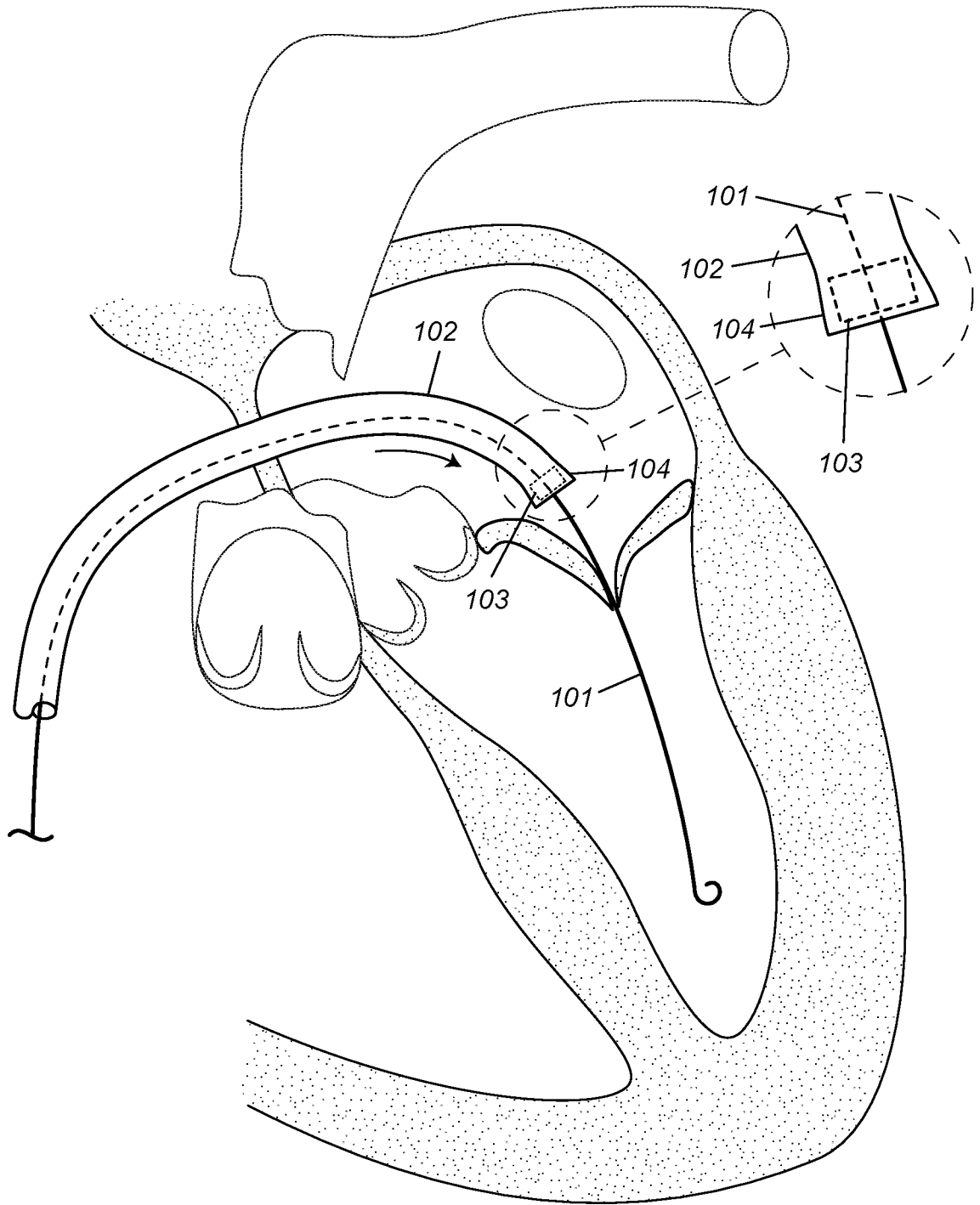


Fig. 1C

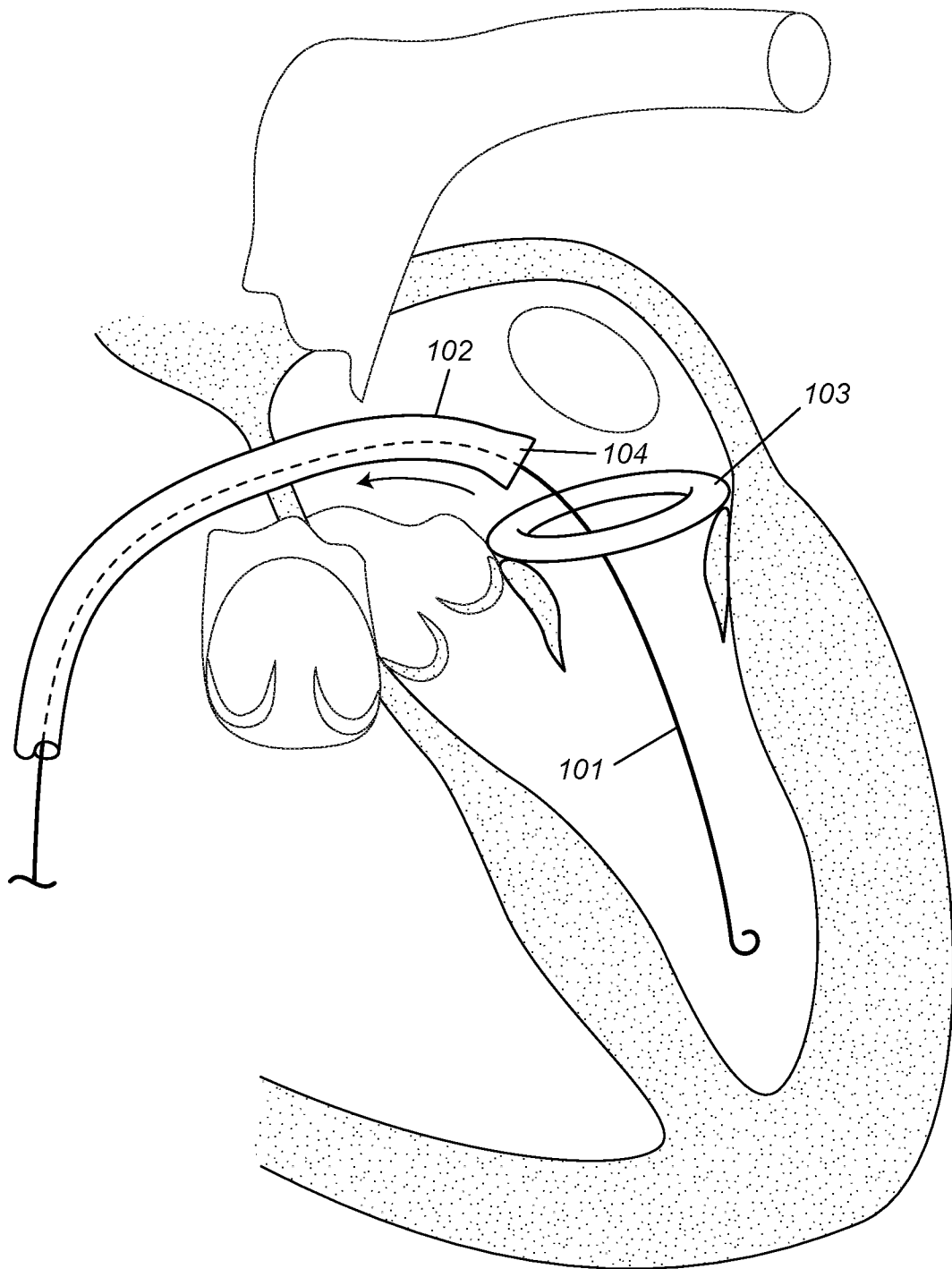


Fig. 1D

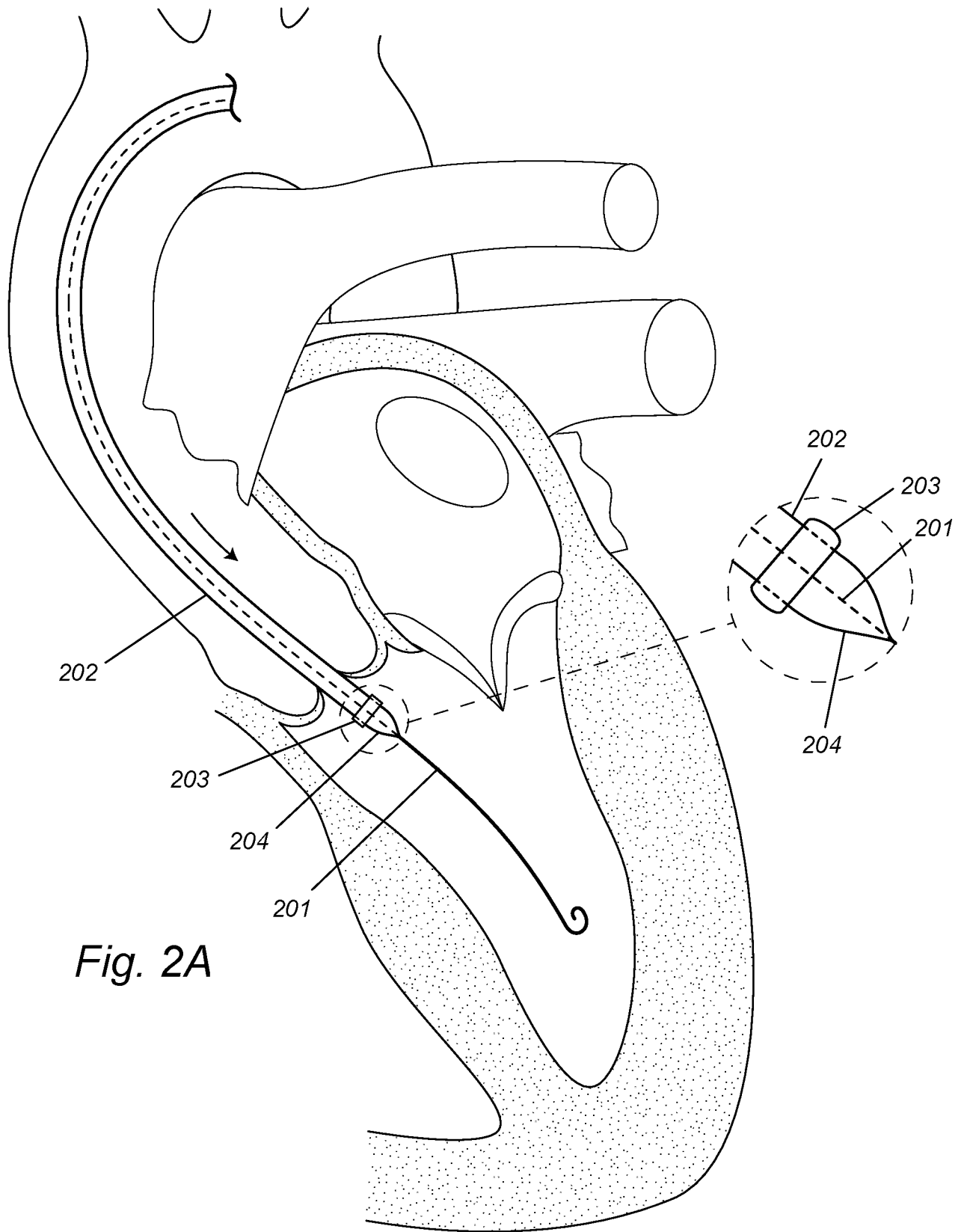
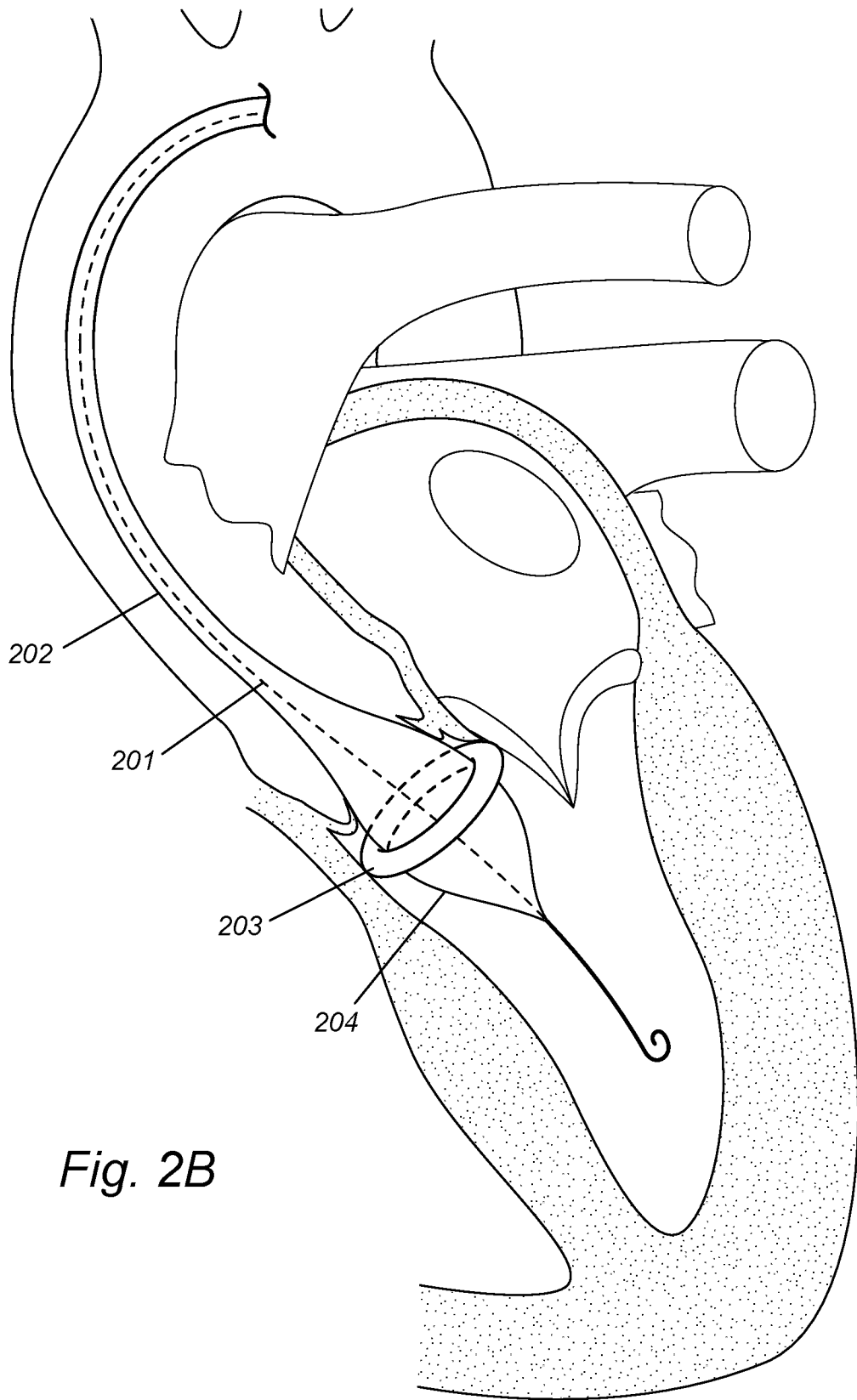
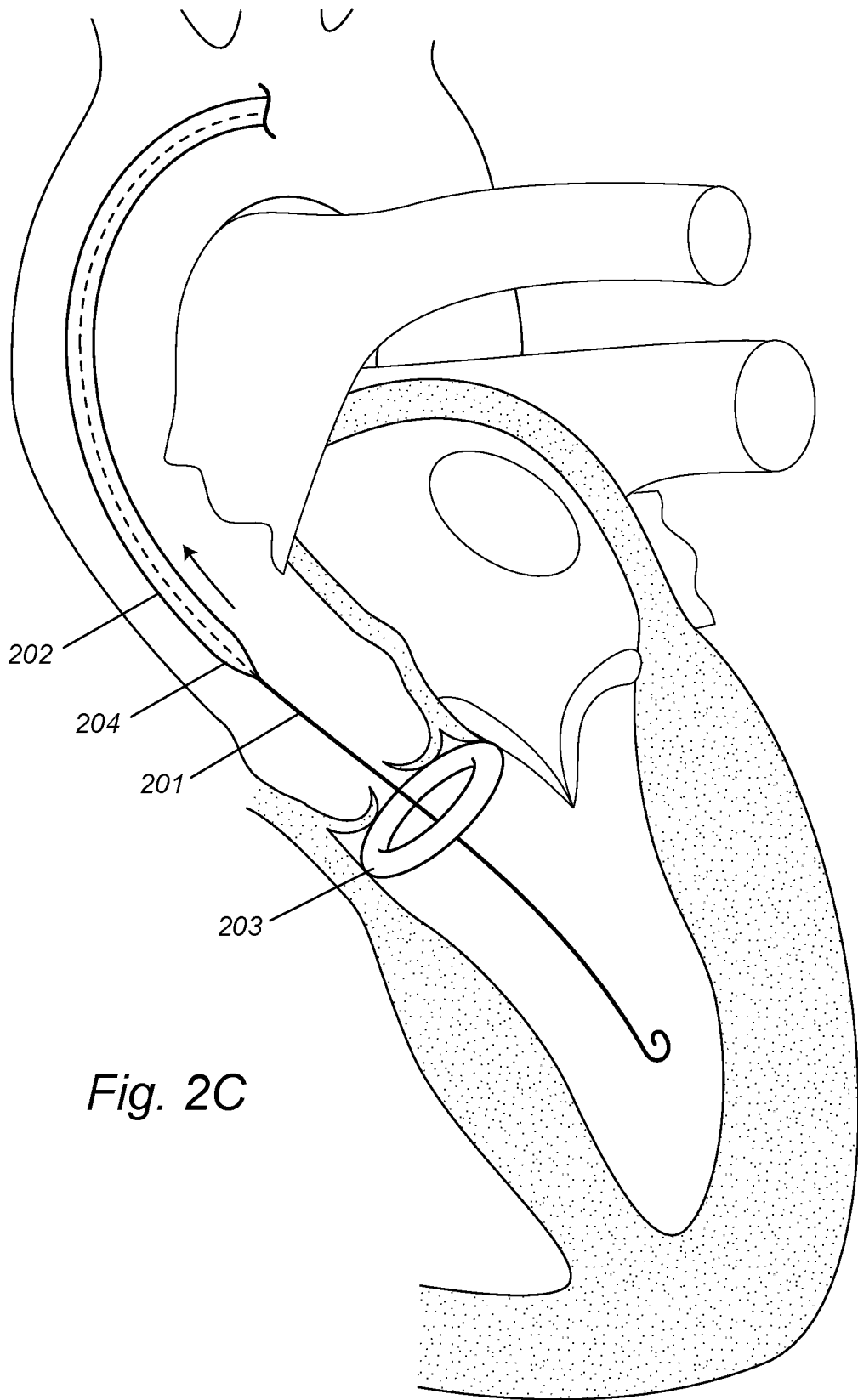


Fig. 2A

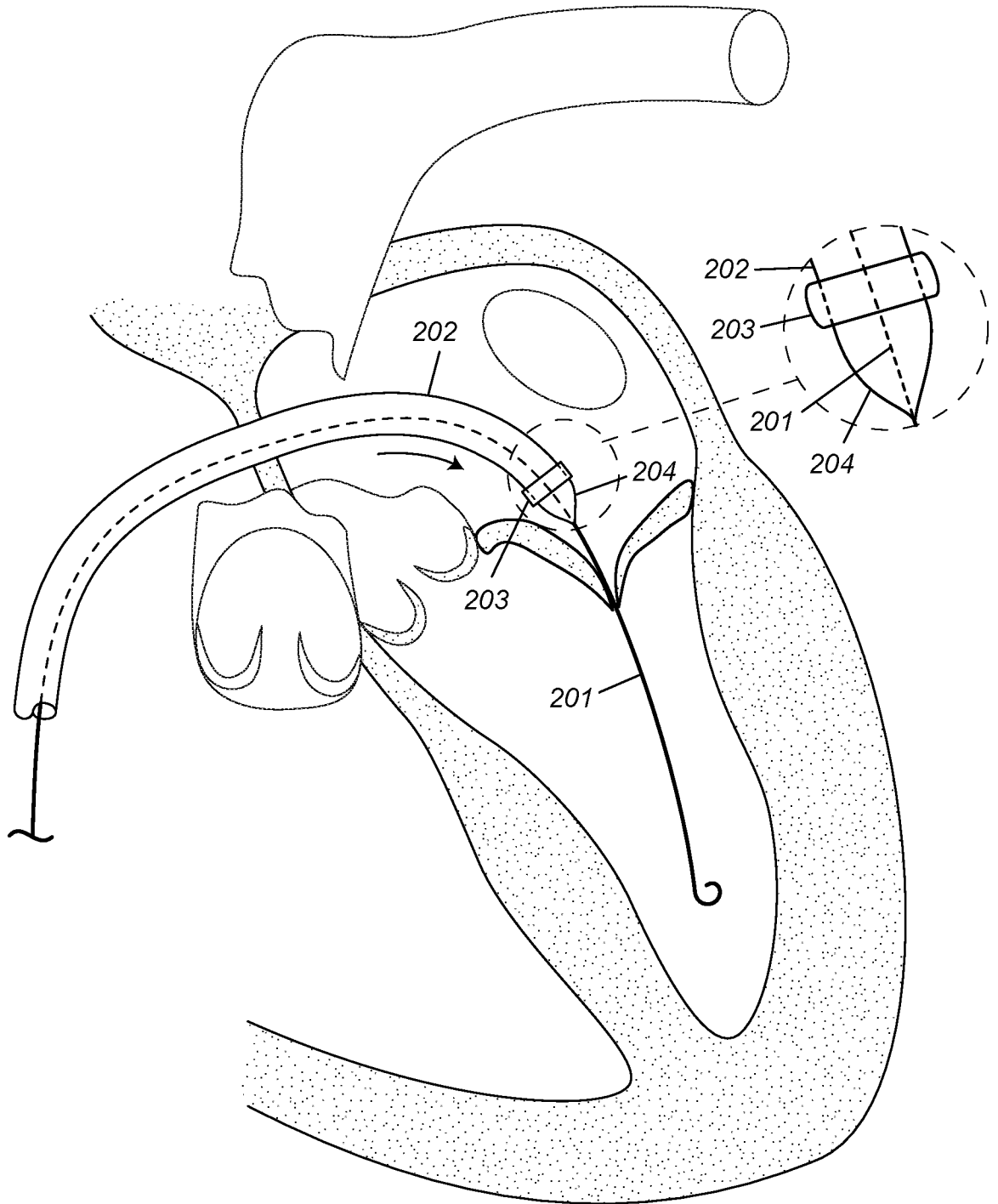


*Fig. 2B*



*Fig. 2C*





*Fig. 2D*

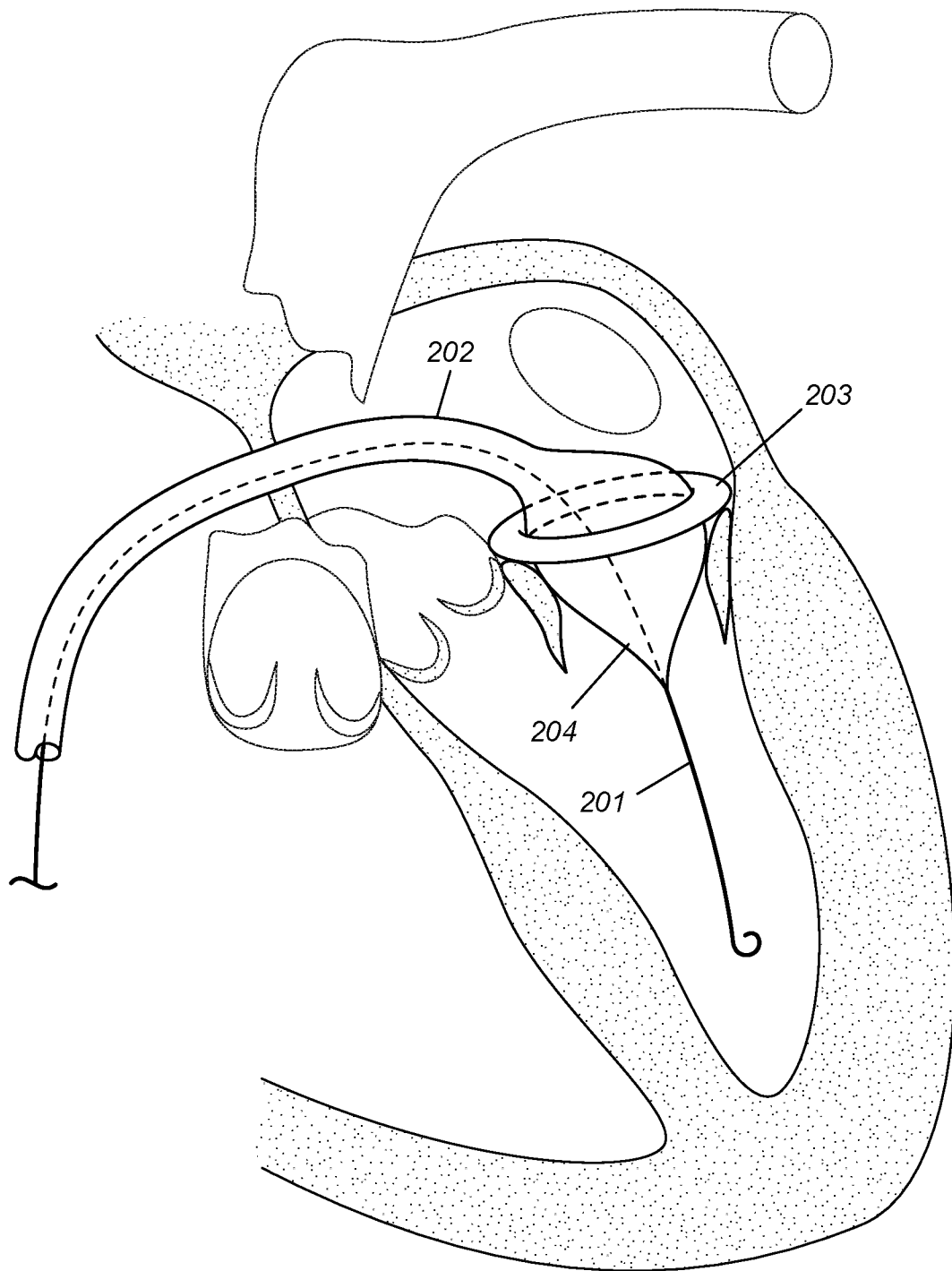


Fig. 2E

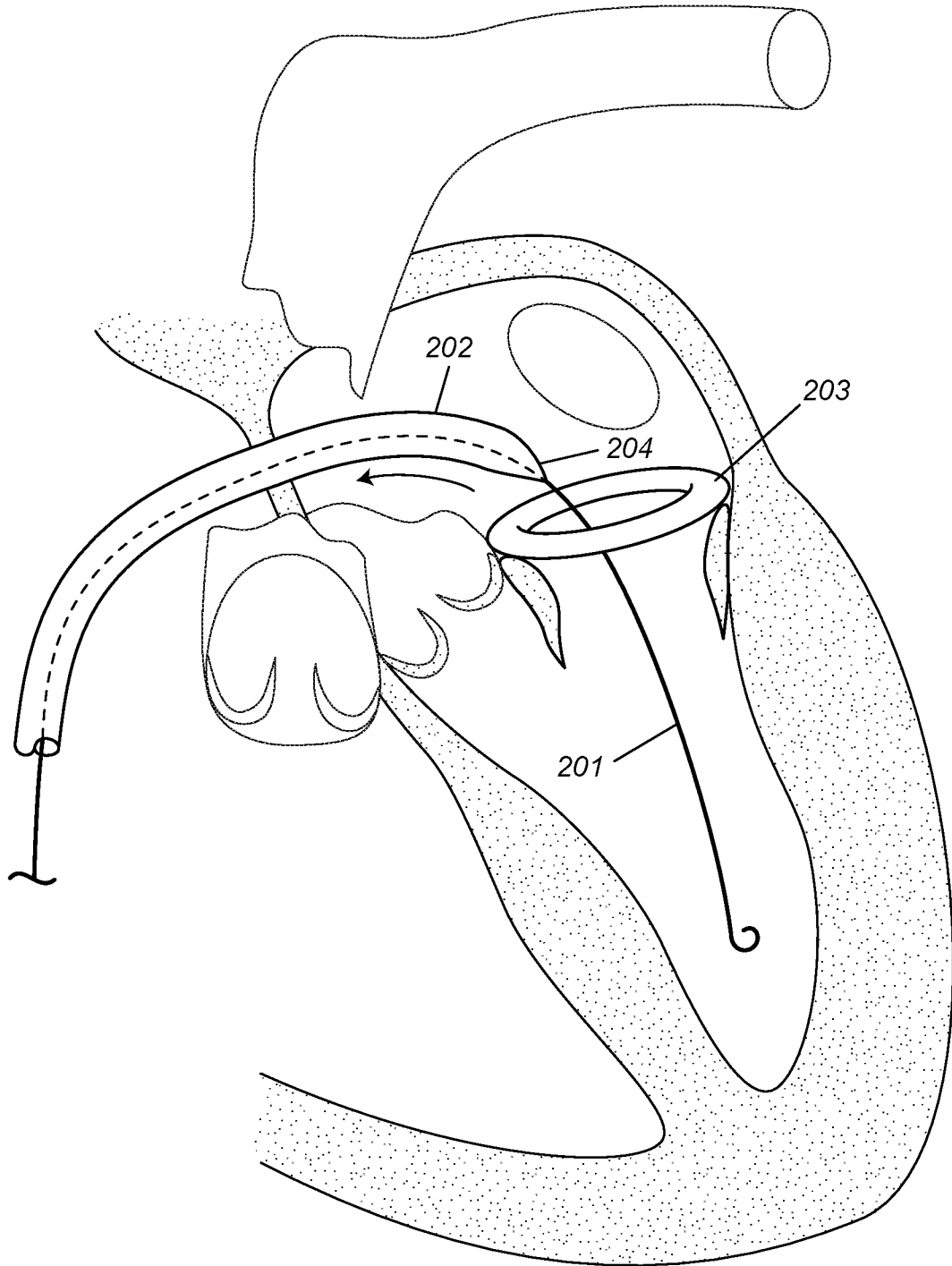


Fig. 2F

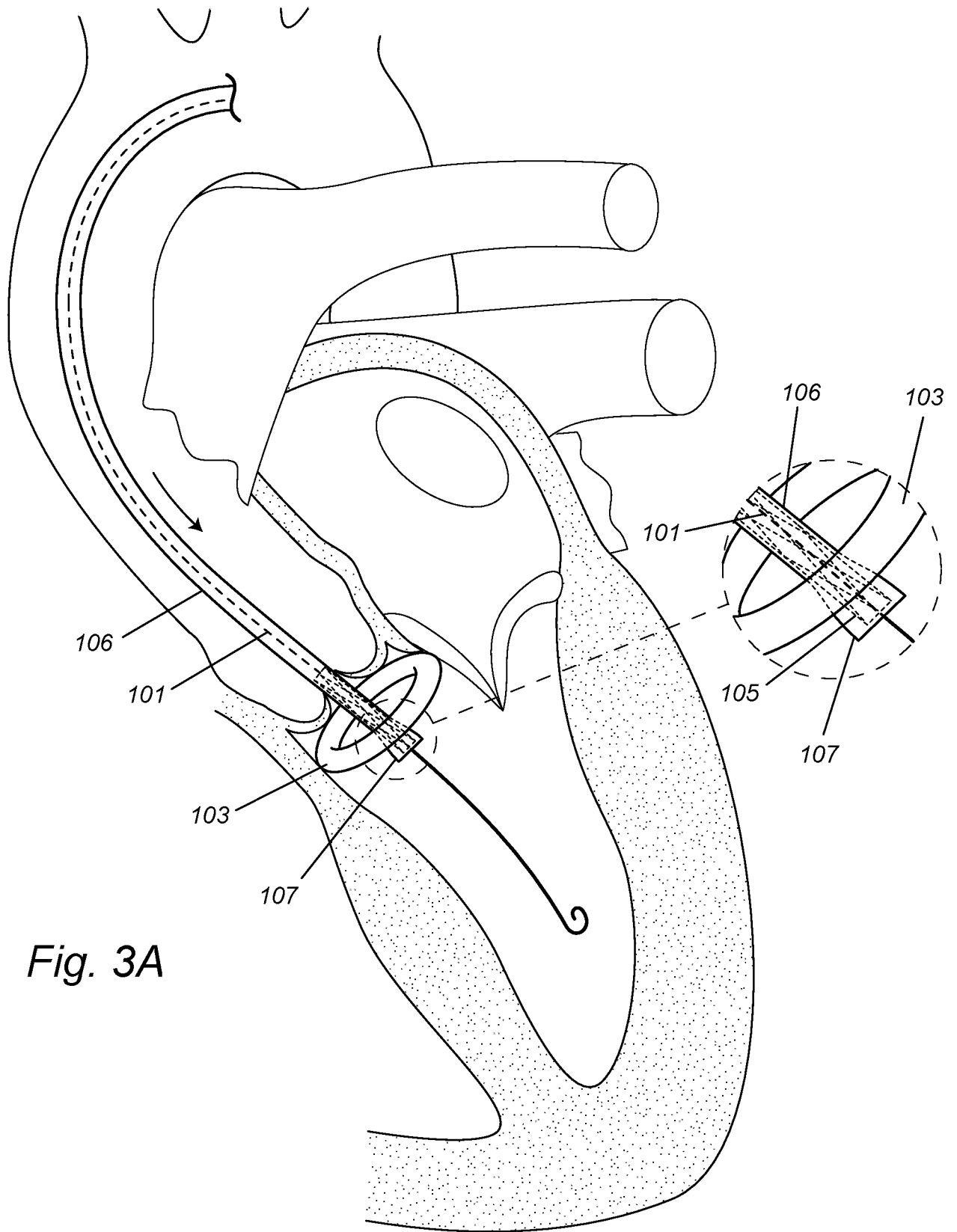


Fig. 3A

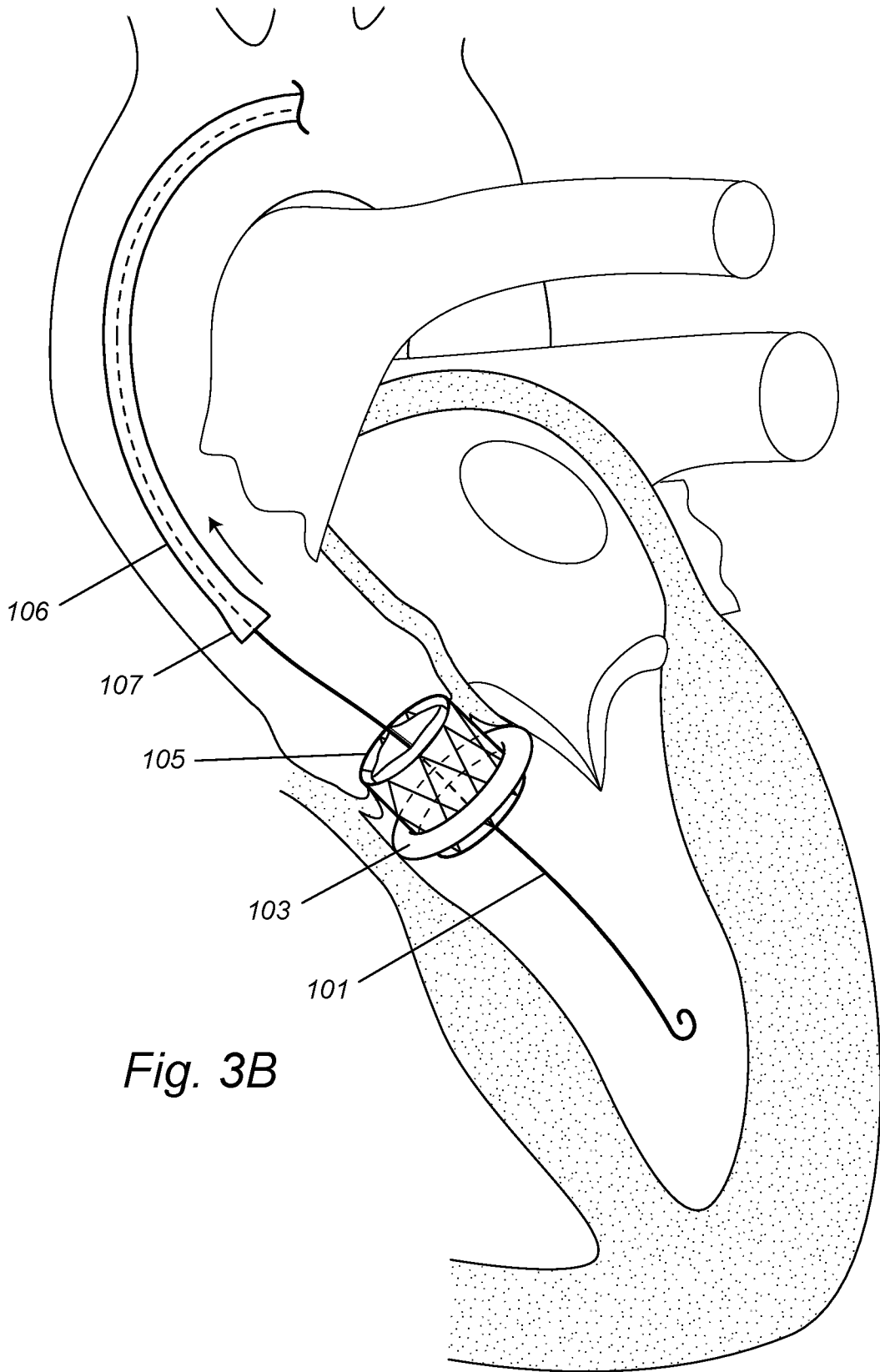


Fig. 3B

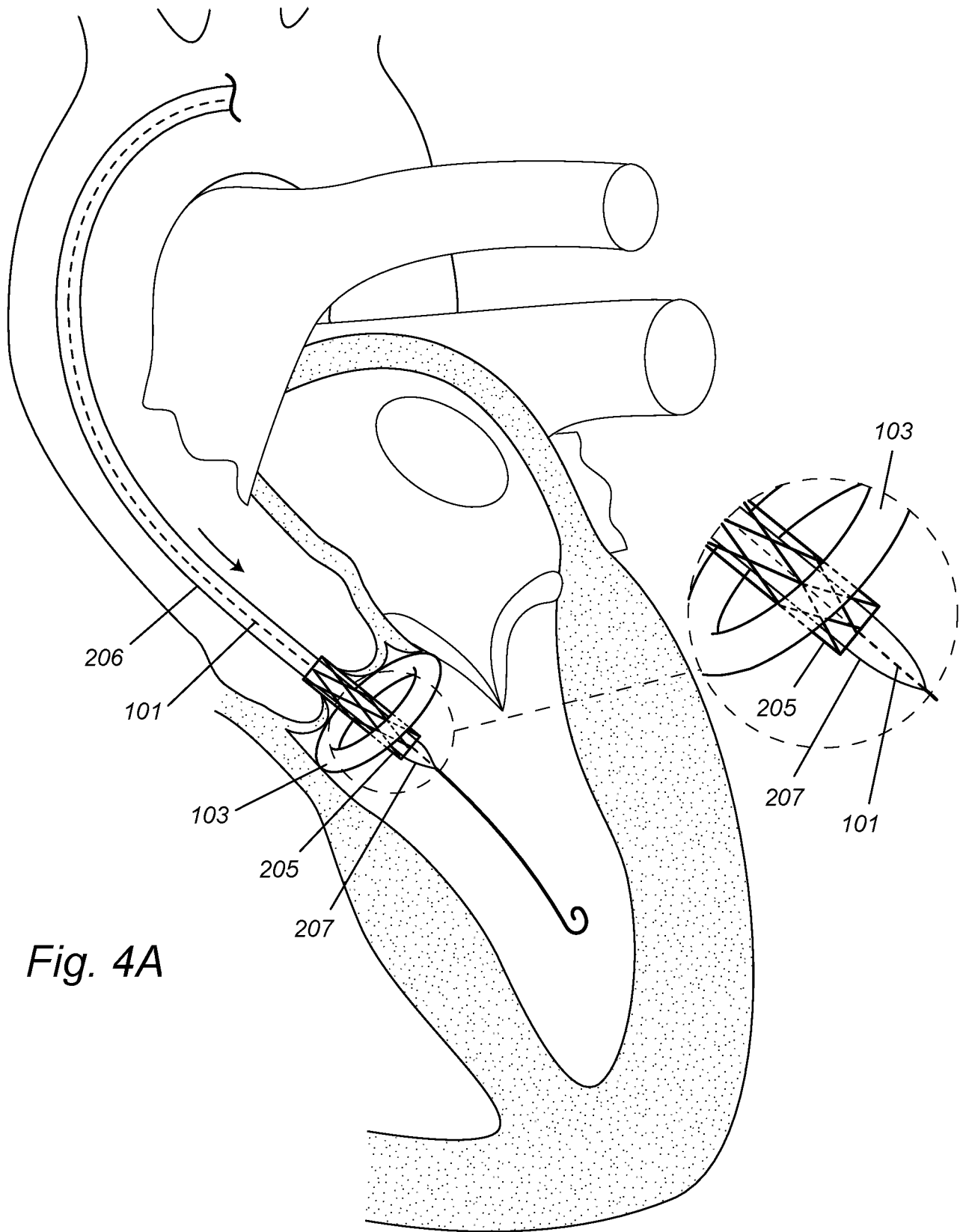


Fig. 4A

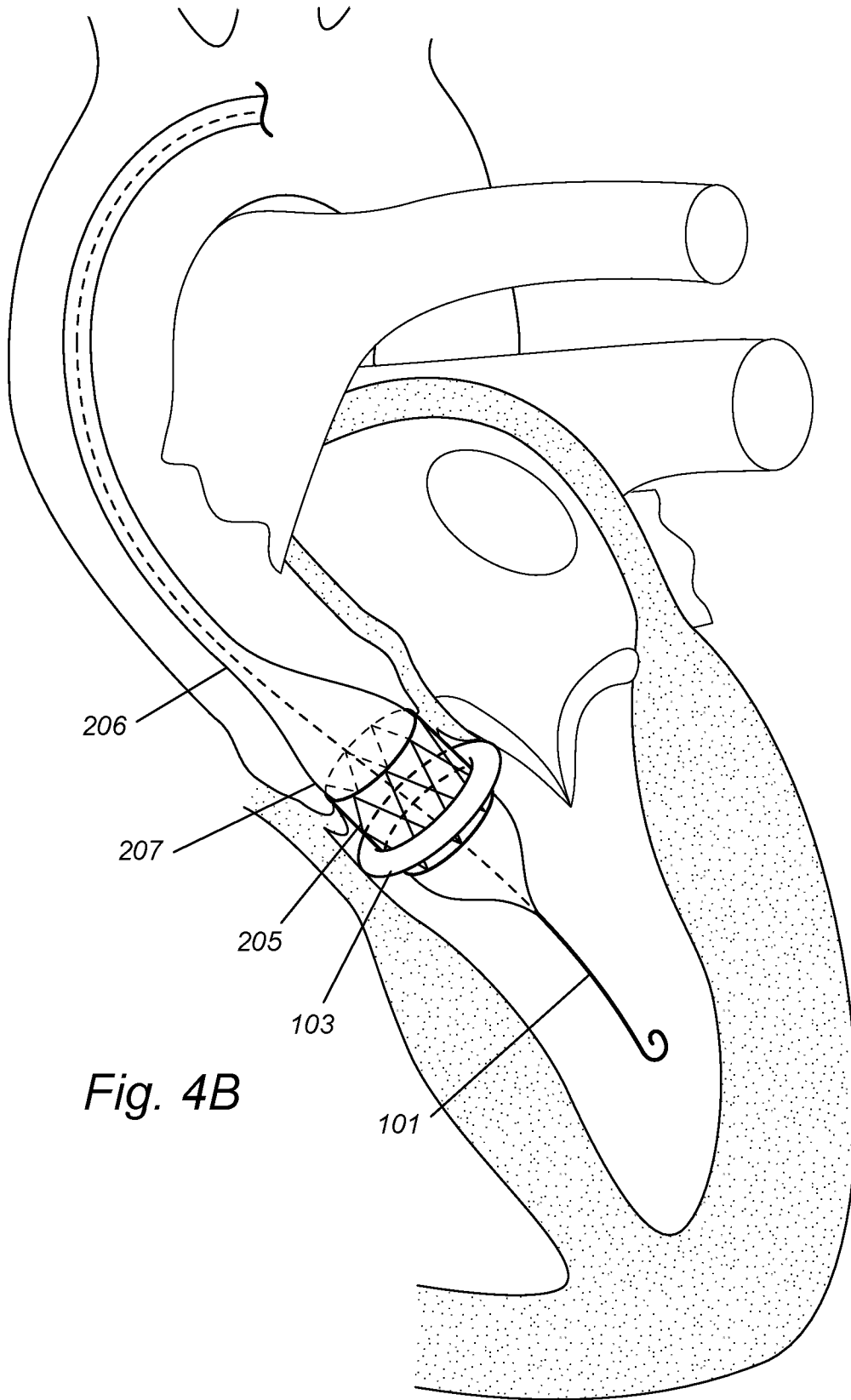


Fig. 4B

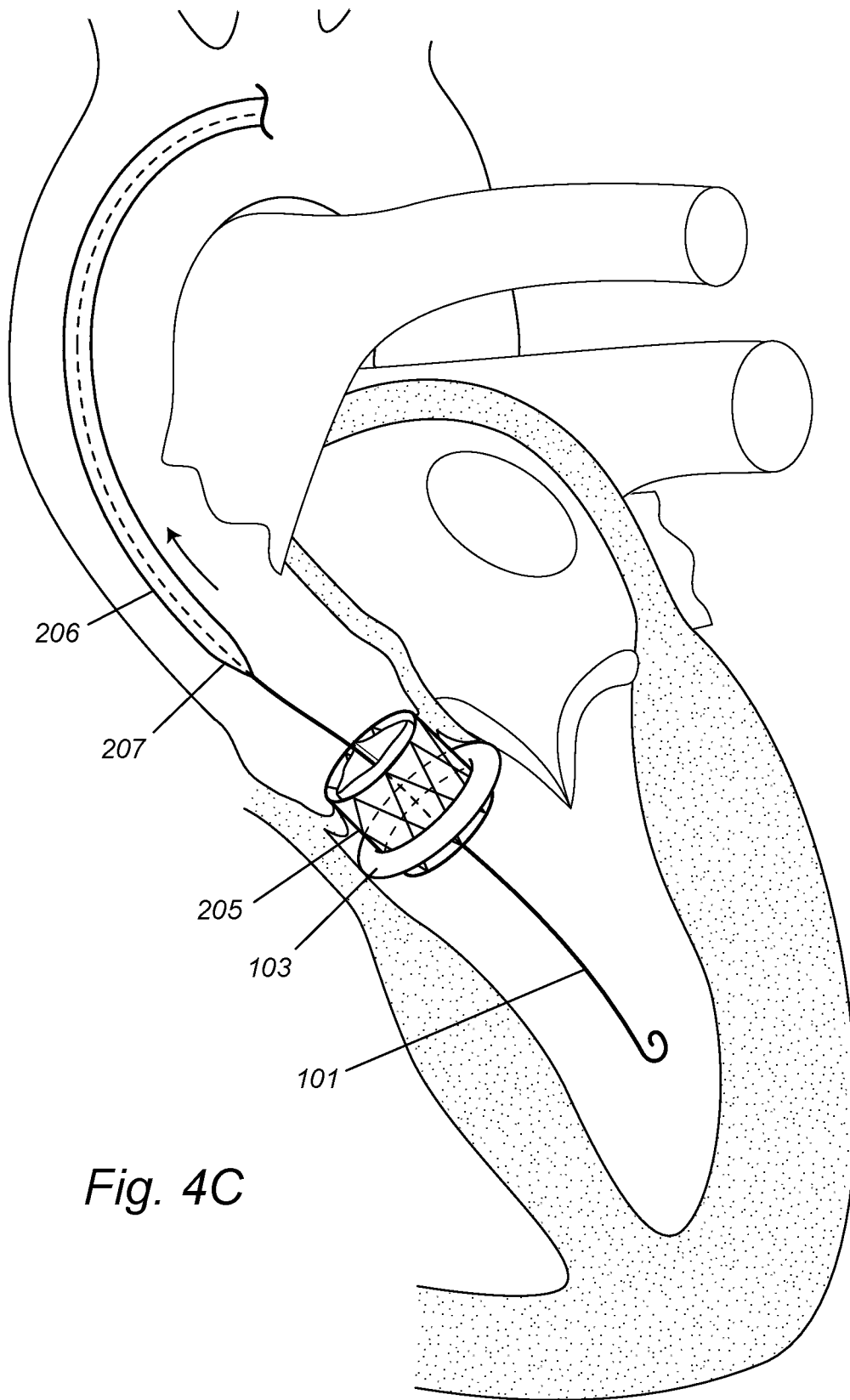
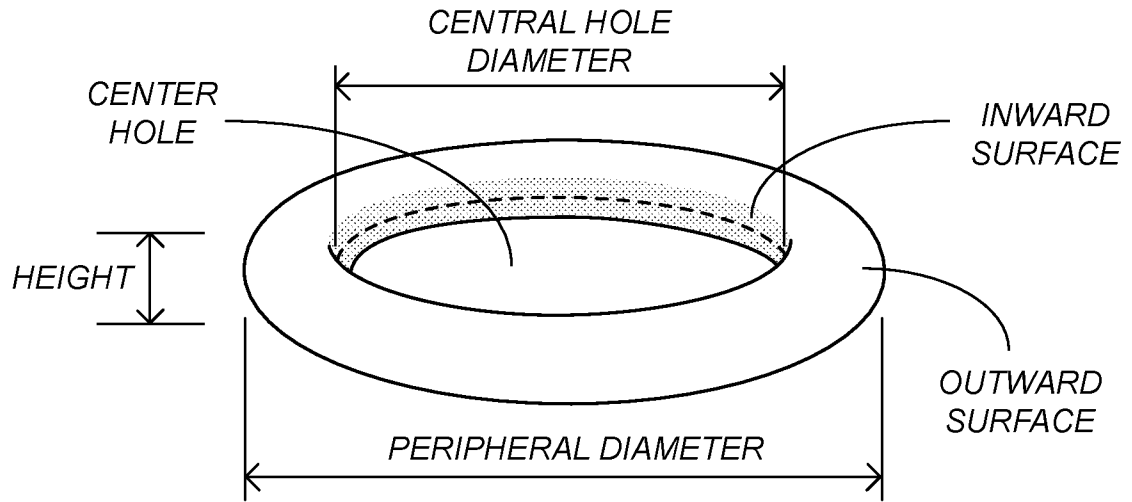
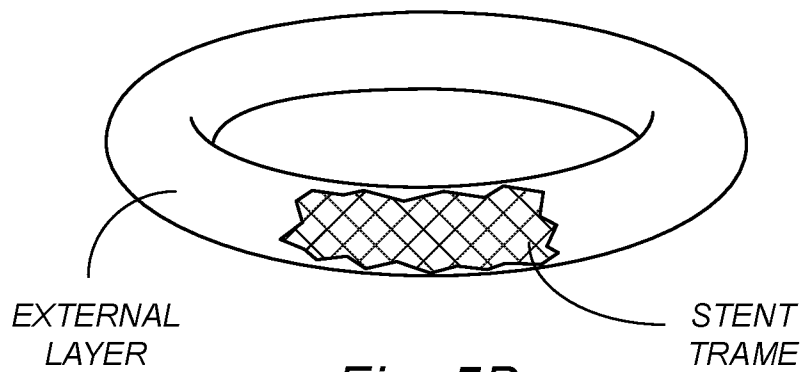


Fig. 4C





*Fig. 5A*



*Fig. 5B*

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/021866

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61F 2/06; A61F 2/24; A61F 2/82 (2016.01)

CPC - A61F 2/2409; A61F 2/2418; A61F 2/2427; A61F 2/2436; A61F 2/2442; A61F 2/2445 (2016.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - A61F 2/06; A61F 2/24; A61F 2/82 (2016.01)

CPC - A61F 2/2409; A61F 2/2418; A61F 2/2427; A61F 2/2436; A61F 2/2442; A61F 2/2445 (2016.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 623/2.11, 2.17, 2.18, 2.36, 2.37, 2.38 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar

Search terms used: annuloplasty, two part valve, heart valve prosthesis, orientation of heart valve, support ring for heart valve

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2014/0200662 A1 (MVALVE TECHNOLOGIES LTD) 17 July 2014 (17.07.2014) entire document	1-5, 7-21, 27, 28, 30-39 --- 6, 22-26, 29
Y	US 6,350,282 B1 (EBERHARDT) 26 February 2002 (26.02.2002) entire document	6
Y	US 2014/0350669 A1 (THE TRUSTEES OF THE UNIVERSITY OF PENNSYLVANIA) 27 November 2014 (27.11.2014) entire document	22-24, 29
Y	US 2013/0261739 A1 (KUEHN et al) 03 October 2013 (03.10.2013) entire document	25, 26

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"E" earlier application or patent but published on or after the international filing date

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"O" document referring to an oral disclosure, use, exhibition or other means

"&" document member of the same patent family

"P" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search

Date of mailing of the international search report

03 May 2016

23 MAY 2016

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